Space Synthetic Biology (SSB)

Completed Technology Project (2011 - 2014)

Project Introduction

This project focused on employing advanced biological engineering and bioelectrochemical reactor systems to increase life support loop closure and *in situ* resource utilization capabilities, and reduce mission equivalent system mass (ESM) in space. The Synthetic Biology Environmental Control and Life Support System (SB-ECLSS) element involved the development of a novel bioelectrochemical reactor concept system to treat human urine while converting the resultant carbon dioxide to methane and water. Advanced techniques were employed to develop highly adapted microbial communities. The anode and cathode compartments demonstrated functionality separately and when integrated, though performance requires improvement for future utilization. Bioelectrochemical systems are a platform technology, as it is possible to convert carbon dioxide to additional products including food, fuels, biopolymers and pharmaceuticals.

The overall goal of the SSB project was to demonstrate Synthetic Biology-enabled technologies that redefine the trade space for advanced biological ECLSS, quantify design trades between purely physicochemical ECLSS and SB-ECLSS and define a roadmap for demonstrating and integrating SB-ECLSS in future destination systems and for developing risk-reducing prototypes. The component technologies developed by this project are aligned with NASA Strategic Plan (NPD 1001.0B) Objective 1.1: Expand human presence into the solar system and and to the surface of Mars to adnvance exploration, science, innovation, benefits to humanity, and international collaboration. The project is also aligned with Technology Roadmap areas TA06 (Human Health, Life Support and Habitation Systems) and TA07 (Human Exploration Destination Systems). Integrated system demonstrations will help to define pathways for incorporation of Synthetic Biology into future mission scenarios.

The SB-ECLSS project consisted of six major tasks areas which included:

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Table of Contents

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Center / Facility:

Ames Research Center (ARC)

Responsible Program:

Game Changing Development

- Systems analyses and technology down-selection – Multiple bioelectrochemical system (BES) scenarios for use in human space missions were generated and analyzed, which led to the down selection of a specific BES technology application (wastewater treatment with simultaneous conversion of process CO_2 to methane)
- Developing the wastewater treatment anode compartment – Experimentation was conducted to develop a urine treating anode compartment without a biological cathode. This was conducted in small scale and then a prototype reactor.
- Developing the CO_2 conversion cathode compartment – Extensive work was conducted to discover, identify and characterize electromethanogens that are capable of convert CO_2 to methane using electricity as their energy source. This was conducted in small-scale reactors without a biological anode. Tools and metabolic pathways were identified to facilitate both organism and physical system engineering.
- Integrated BES prototype reactor development and testing – A prototype reactor was developed to test the integration of the separately-developed anode and cathode microbial communities. The system under went iterations of design to optimize reactor operation.
- Developing a reactor gas management system – A system concept and some hardware were developed that allow CO_2 introduction into the BES reactor with simultaneous methane removal. This gas separation test stand has broad applicability for biological systems in spaceflight.
- Generate concepts for BES operation in space – Integration concepts were developed that indicate how a BES system would be employed in spaceflight.

Anticipated Benefits

The technology primarily benefits exploration missions where multifunctional systems that help close life support loops and enable i*n situ* resource utlization will be required to reduce dependence on resupply from Earth.

Project Management

Program Director:

Mary J Werkheiser

Program Manager:

Gary F Meyering

Project Manager:

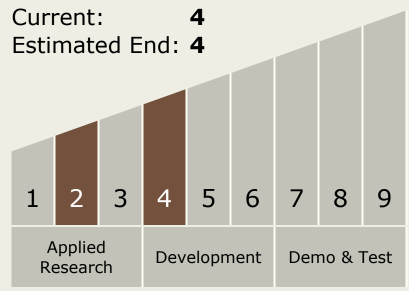
Laura Lewis

Principal Investigator:

Stephen J Horan

Technology Maturity (TRL)

Start: **2**
Current: **4**
Estimated End: **4**

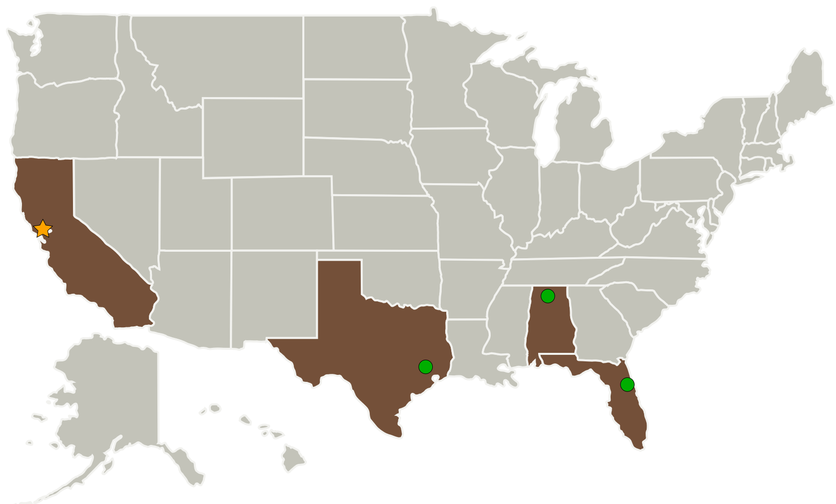


Technology Areas

Primary:

- TX07 Exploration Destination Systems
  - └ TX07.2 Mission Infrastructure, Sustainability, and Supportability
    - └ TX07.2.1 Logistics Management

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★Ames Research Center(ARC)	Lead Organization	NASA Center	Moffett Field, California
J. Craig Venter Institute, Inc.	Supporting Organization	Industry	La Jolla, California
●Johnson Space Center(JSC)	Supporting Organization	NASA Center	Houston, Texas
●Kennedy Space Center(KSC)	Supporting Organization	NASA Center	Kennedy Space Center, Florida
●Marshall Space Flight Center(MSFC)	Supporting Organization	NASA Center	Huntsville, Alabama
University of California-Santa Cruz	Supporting Organization	Academia	Santa Cruz, California

Primary U.S. Work Locations	
Alabama	California
Florida	Texas